METHOD AND DEVICE FOR DETERMINING VOLUMES IN THE HUMAN OR ANIMAL BODY

The invention pertains to a method and a device for determining volumes in human bodies or animal bodies. In this case, image data of an interesting volume are acquired by means of a suitable imaging method and subjected to a manual, semi-automated or fully automated segmenting process. Dimensional information on the interesting volume is then automatically determined from the segmented image data.

Such methods and devices are known in various forms. They provide information that, among other things, is used by physicians, e.g., in the diagnosis of tumors, in choosing the appropriate therapy and in monitoring the progress of the therapy, as well as in organ transplants.

The known methods and devices proved quite effective in practical applications, with particular advances having been achieved in semi-automated and the fully automated segmenting processes in recent years. In this respect, the term "segmenting" refers to the process called "image comprehension," namely the transition of a certain quantity of pixels of a plurality of pixels (or - in volume data records - voxels) into a symbolic description (tumor, bones, etc.). Such a segmenting process is composed of a classification, namely the formation of equivalence classes in the characteristic space, and an identification, i.e., an inverse transformation of the elements of an equivalence class from the characteristic space into the local space.

The invention is based on the objective of disclosing a method and a device for determining volumes in human bodies or animal bodies, in which the accuracy of the determined values and the ability to interpret said values is significantly improved in comparison to known methods and

devices. In addition, it should be possible to easily utilize the new method and the new device in combination with or as a retrofitting option for known methods and devices.

The first aspect of this objective is attained with a method of the initially described type, in which at least one characteristic value is assigned to the steps in which the image data is acquired and segmented, with the characteristic value representing a measure for the error occurring in these steps, and in which an error value is determined from the assigned characteristic value in the form of a measure for the error occurring in the determination of the dimensional information, with the error value being displayed or output, respectively. It is preferred that the error value can be assigned to the dimensional information such that these two values can be archived in a correlated fashion.

It would also be possible to respectively assign at least one characteristic value that respectively represents a measure for the errors occurring in the respective step to the steps in which the image data are acquired and segmented. These characteristic values can then be linked to form a characteristic value and used in this fashion or used separately.

Known methods and devices frequently give the user the wrong impression that the obtained values are absolutely accurate because error limits are not indicated. This can have fatal consequences, in particular, with respect to the fact that the users of such methods usually are highly stressed physicians who are unable to evaluate which inaccuracies caused, in particular, due to physical circumstances are incorporated into the final value at which point of the determination process. In addition, a fast decision in interpreting the data delivered by known

methods and devices is necessary for cost reasons. For example, it may occur that, during the monitoring of the therapy progress, the volume of a tumor is initially determined to be 50 ml, then 48 ml and ultimately 43 ml with a known method. This apparently indicates that the therapy is effective. Due to technical, physical or biological peculiarities, the inaccuracy of the measurement may actually differ and, for example, amount to +/- 2 ml in the first measurement, +/- 4 ml in the second measurement and +/-7 ml in the third measurement. This means that the actual volume of the tumor may have been only 48 ml in the first measurement and 49 ml in the last measurement. This indicates that the chosen therapy, e.g., chemotherapy, is not effective and that another type of therapy, e.g., radiation therapy, should be started as soon as possible.

The method according to the invention increases the accuracy of the thusly determined data significantly. If the method is, for example, used in the field of medicine, in particular, tumor medicine, the treating physician is able to evaluate the volume information that is essential for deciding on the corresponding therapy and for monitoring the progress of the therapy in a significantly more differentiated fashion since it is now possible to indicate error limits. The decision process is significantly simplified for the physician, and the physician does not require detailed information on the usually very complicated technique and its physical aspects.

The method provides the additional advantage that it can be utilized in all types of imaging methods, e.g., CT, MRT, PET, ultrasound, etc. In this respect, it is merely required to adapt the parameter or the parameters that are dependent on the respective method. Depending on the type of imaging method used, the at least one characteristic value assigned to the step in which the image data is

acquired usually contains at least one measure of the following group of measures: signal-to-noise ratio (e.g., influenced by the tube voltage, the tube current or the reconstruction kernels), tissue contrast, pitch and/or increment (in spiral-CT), sequence parameters (in MRT), layer thickness, matrix size and/or filter used.

If a semi-automated or fully automated segmenting process is carried out, the at least one characteristic value assigned to the segmenting step may contain a measure for the accuracy of a segmenting method used in the segmenting process and/or a measure for the reproducibility of the results of the segmenting method used.

However, if a manual or semi-automated segmenting process is carried out, it is preferred to assign a personal characteristic value to each person carrying out the method, and to take this personal characteristic value into consideration in determining the error value of the dimensional information. This advantageously makes it possible to incorporate the different segmenting capabilities of the persons carrying out the method into the determination of the error value, i.e., it can be taken into consideration that the accuracy of volumes determined from image data records which were segmented by a skilled person is higher than the accuracy of volumes determined from image data records which were segmented by unskilled persons.

In this case, the personal characteristic value assigned to each person can be automatically determined, e.g., by having the respective persons carry out one or more manual or semi-automated segmenting process(es) with predetermined test data. A self-learning system can be realized in this fashion. In this respect, it may be advantageous if the operating personnel carries out segmenting processes with test data within regular or irregular intervals.

Fluctuations in the performance of the individual operators which may depend on their shape on the day in question or the like can be detected by segmenting respectively identical test data. In order to determine learning effects, respectively different test data may be used for determining the personal characteristic value. It goes without saying that both aforementioned methods may also be used cumulatively, i.e., part of the test data is repeatedly segmented and another part is presented to the operator much less frequently. The former part makes it possible to determine, for example, an error bandwidth, and the latter part of the test data provides information, for example, on learning effects.

In one advantageous variation of this method, at least one characteristic value is assigned to the interesting volume and taken into consideration in determining the error value of the dimensional information. Depending on the type of structure contained in the interesting volume, e.g., a tumor or an organ, its size and/or shape, for example, play a different role in the determination of the accuracy and the error interval of the volume value.

The second aspect of the aforementioned objective is attained with a device for determining volumes in human bodies or animal bodies which contains means for inputting image data of an interesting volume, means for segmenting the image data in a manual, semi-automated or fully automated fashion and means for automatically determining dimensional information on the interesting volume from the segmented image data, wherein said device is equipped with at least one data memory, in which characteristic values are stored that can be assigned to the input data and/or the segmented image data in accordance with predetermined criteria, and wherein the means for automatically determining the dimensional information are coupled to the at least one data memory and realized in such a way that

they are able to read the characteristic values out of the data memory and determine an error value in the form of a measure for the error occurring in the determination of the dimensional information from the characteristic values.

The device also represents a low-cost retrofitting option for existing systems, in particular, complicated medical imaging devices, e.g., a nuclear magnetic resonance tomography device or a computer tomography device. The invention not only improves the accuracy of the data delivered by existing devices, but can also universally utilized in a cost-effective fashion.

In one preferred embodiment of the invention, a characteristic value that is assigned to the interesting volume is also stored in the data memory such that the accuracy is additionally improved and physical and biological peculiarities can also be taken into consideration.

Characteristic values for each person operating the device may be alternatively or additionally stored in at least one data memory that is coupled to the means for determining the dimensional information. These characteristic values would make it possible to take into consideration the individual abilities of the respective persons during the segmenting process for determining the dimensional information and, in particular, an error interval assigned to the dimensional information. In this respect, it is advantageous to provide a data memory with test data records, on which the persons operating the device can carry out a manual or semi-automated test segmenting process in order to obtain reproducible and comparable information on the individual segmenting abilities. In this case, the evaluation of the test segmenting process, as well as the determination and storage of a personal

characteristic value for the respective person may also be realized automatically.

If it is - as deemed practical in numerous applications - planned to repeatedly test the individual segmenting abilities of the operating personnel within regular or irregular intervals, it is, according to the invention, possible to assign a data record to the individual characteristic values which identifies the test data record(s) used for determining the respective characteristic value. Due to this measure, it can be advantageously ensured that one and the same person receives a defined test data record during repeated test segmenting processes. For example, the test data record may contain test data that are repeatedly presented to this person so as to ascertain the error bandwidth of this person during the segmenting process. The test data record may also contain test data that is presented to the person only once or within longer intervals such that training effects caused by the frequent segmenting of identical test data and similar effects can also be determined. It would, for example, also be possible to respectively change only one or two or very few test data in a test data record for each new test segmenting process, with the remaining data not being changed.

In normal instances, it is practical to equip the device with means for illustrating and/or outputting the determined dimensional information and the determined error value. Monitors, printers, hard drives, CD-ROMs and diskettes may, in particular, be considered for this purpose.

The scope of the invention allows numerous modifications and additional developments that, for example, pertain to the type of characteristic values and their determination, as well as the measure for the error in the automatically

determined dimensional information which is derived thereof. In any case, it is essential to the invention that, when determining the volume, an error value for the dimensional information is determined and specified in addition to the dimensional information.

One possible embodiment of the invention is described below with reference to a semi-automated segmenting process which represents the most complex instance for realizing the present invention. In this case, one needs to differentiate between user-independent and user-dependent errors. In manual segmenting processes, only user-dependent errors are of decisive importance. Only user-independent errors are important in a fully automated segmenting process. However, both types of errors need to be taken into consideration in a semi-automated segmenting process.

One also needs to differentiate between independent and dependent errors. Independent errors in individual characteristic values can be assigned to a certain error source. These individual characteristic values can, for example, be incorporated into the calculation of the total error in the form of error information or in the form of a factor by means of error linking methods or simple multiplicative linking. However, it is known that dependent errors also occur, e.g., the signal-to-noise ratio and the tissue contrast. In this case, the dependence manifests itself with respect to the fact that, in semi-automated and manual segmenting processes, changes of these factors cause a change in the segmenting error which cannot be assigned to only one of the factors. The error caused by such dependent variables may, for example, be stored in a data memory in the form of a table. In this case, the number of dependent variables defines the dimensions of the table, and the table contains in each field a characteristic value or error value that corresponds to the corresponding columns of this table.

These characteristic values or error values are experimentally determined beforehand. This may, for example, be realized in the form of a large number of physicians carrying out test segmenting processes.

In order to determine the error during a concrete segmenting process, the actual values of the dependent variables, e.g., the signal-to-noise ratio and the tissue contrast, are initially determined. This may, for example, be realized in the form of an on-line calculation or a measurement. Subsequently, the errors corresponding to these variables are read out of the table. In this case, interpolations between individual fields of the table can be carried out depending on the respective requirements.

The thusly determined characteristic value or error value can subsequently be linked with independent characteristic values or error values in order to determine the total error. These independent characteristic values or error values may also be defined by a correlation between several variables. An algorithm-dependent error value for the algorithm used in the semi-automated segmenting process, as well as a user-dependent characteristic value or error value, may, in particular, be considered as such independent characteristic values or error values.

It is also possible to store a few or all dependent variables for each respective user. In this case, a predetermined table may, for example, be stored for each user. The accuracy of the error information increases proportionally with the number of variables that can be shifted from the user-independent table to the user-dependent table. In other respects, this has the disadvantage that the individual user or physician needs to segment a relatively large quantity of test data.

It should be emphasized that the method according to the invention and the device according to the invention do not correct measuring errors. The method according to the invention and the device according to the invention for the first time make it possible for an error that always occurs in methods and devices of this type to be incorporated into an evaluation of the measuring result to a relevant degree.

Other advantages, objectives and characteristics of the present invention are described below with reference to the figures that show the sequence of the method for determining a volume in an exemplary fashion. The individual figures show:

Figure 1 a flow chart of the sequence of a volume calculation, and

Figure 2 its chronological progression.

The embodiment shown in the figures is used for determining the volume of tumors, in particular, liver tumors, with a spiral-CT imaging device. A semi-automated segmenting algorithm is used for determining the volume. This means that a user-dependent and a user-independent influence on the accuracy of the volume measurement exist.

This also means that user-dependent and user-independent error components need to be taken into consideration as can be clearly ascertained from the two diagrams. The following parameters may, for example, be identified as influential factors: the size of the tumor as the object parameter, the contrast of the tumor as the imaging parameter and the segmenting algorithm used as the segmenting parameter.

In a first approximation, all remaining parameters can be considered to be constant. It goes without saying that

other parameters may also be considered influential and treated accordingly.

In order to determine a user-independent error, a test series is carried out with a spiral-CT under conventional abdomen imaging adjustments with the aid of a CT-phantom, namely with test objects of different sizes and different densities. The thusly obtained data are contoured with the aid of the related segmenting algorithm. In order to ensure that the result is not dependent on the user, the segmenting process is either carried out by a sufficiently large number of persons or repeated by one person to a sufficient degree. It goes without saying that the term "sufficient" is defined by a statistic convergence. A function f(x,y) that is two-dimensional in this case and describes the error in the volume measurement (f) in dependence on the object size (x) and the contrast (y) is derived from the thusly obtained volume data by mathematical manipulation.

In order to determine the user-dependent error, three representative test data records with clinical instances are chosen and segmented monthly by each user.

The results of these segmenting processes are stored. When the volume measuring system is used, the variability of all results is calculated online and the standard deviation is used as a measure for the user-dependent error. In this context, it would naturally also be possible to utilize other statistic processes for this purpose.

A total error function that is individually adapted to each user is achieved by linking the user-independent error and the user-dependent error - in case of doubt by means of corresponding known mathematical measures.

When the user subsequently carries out a volume measurement on a clinical data record, the error in the determination carried out on the clinical data record is estimated with the aid of the parameters contrast, size of the tumor and user influence. In this embodiment, the result is output in the form volume = xxx,xx ml +/- xx,xx ml. The progress of a therapy can be controlled much more precisely in this fashion because the user is also provided with information on the accuracy of the respective measurement. This is particularly important if, for example, the volume of the tumor apparently decreases during treatment while the corresponding error increases superproportionally, i.e., an increase in the volume of the tumor could occur due to the limited measuring accuracy. In such instances, appropriate measures for increasing the measuring accuracy would have to be carried out before the therapy can be deemed successful.